(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 353 299 B1**

(12) # EUROPEAN PATENT SPECIFICATION

(45) Date of publication of patent specification: **21.04.93**

(51) Int. Cl.5: **A61B 6/03**, G06F 15/62

(21) Application number: **88900101.2**

(22) Date of filing: **11.12.87**

(86) International application number:
PCT/JP87/00972

(87) International publication number:
WO 88/04156 (16.06.88 88/13)

(54) **CONVOLUTION PROCESSING METHOD FOR X-RAY TOMOGRAPHIC EOUIPMENT.**

(30) Priority: **12.12.86 JP 296173/86**

(43) Date of publication of application:
07.02.90 Bulletin 90/06

(45) Publication of the grant of the patent:
21.04.93 Bulletin 93/16

(84) Designated Contracting States:
DE GB NL

(56) References cited:
JP-A-61 290 573
US-A- 4 250 387
US-A- 4 326 252
US-A- 4 654 796

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Description

Technical Field

The present invention relates to an improvement of a deconvolution processing method for eliminating a blur of a reconstructed image in an X-ray tomographic apparatus.

Background Art

The schematic construction of an X-ray emission mechanism and an X-ray detection mechanism of an X-ray tomographic apparatus is illustrated in Fig. 3. That is, the X-rays emitted from an X-ray tube are shaped into a fan beam by a collimator 2, transmitted through a reconstruction region 3 in which is placed a body or an object and impinge on an X-ray detector 4 so that the strength of the X-rays incident on respective channels is detected asn an electrical signal. As shown in Fig.4,the electrons 31 emitted from a cathode (not shown) impinge on a target 7 on a rotating anode 6 so that the bombardment energy of the electrons is converted into the X-ray beam 32 which is radiated. Reference numeral 8 designates a focal point on the target 7 which radiate the X-rays in response to the bombardment by the electrons;9, an anode shaft supporting the target 7 which is rotatably supported by bearings 10. The focal point 8 has an extremely small area so that the X-ray radiation becomes the plane radiation. Of the electrons radiated toward the focal point 8, some electrons are rebounded from the forcal point 8 and impinge again on the surface of the target 7 except the focal point so that the X-rays radiated from afocal points excet the focal point 8 are produced. The X-rays radiated from the plane focal point and the X-rays radiated from the afocal points are the cause for bluring an image obtained by the tomographic apparatus.

In order to eliminate such blur, the data detected from each channel of the X-ray detector is subjected to the deconvolution processing which will be describe briefly below. For instance, when the X-rays are radiated by locating a pin target in the reconstruction region 3 in the mechanism shown in Fig.3, tje X-ray detection signal corresponding to the shadow of the pin target is obtained from the X-ray detector 4 as shown in Fig.5. In Fig.5,the abscissa designates the positions of the channels of the X-ray detector while the ordinate represents the X-ray strength. Reference numerals 21 and 22 denote the shadows of the pin and 21 indicates the umbra while 22,the penumbra which causes a blur. The function used to express the profiles such shadows is PSF (Pint Spread Function) which represents the characteristic of the X-ray tube. In order to eliminate a blur, the data of all the channels of the X-ray detector are subjected to the deconvolution processing by utilizing the inverse function obtained in correspondence with PSF. That is, in correspondence with PSF obtained as a function of the positions of the channels as shown in Fig.6A,an inverse function 23 which is a function of the positions of the channels is obtained as shown in Fig.6B. When the deconvolution processing is carried out by using this inverse function and the data of the channels in a range in which is defined a function,the channel data 21 excluding any blur can be obtained as shown in Fig.6C.

When the convolution processing is carried out in the manner described above,the skirt of PSF spreads over many channels because the prenumbral portion due to the radiation of the X-rays from the afocal points extends over a wide range. As a result,the skirt of the inverse function also spreads accordingly so that the channnel data which are used in one convolution operation are increased in number. Furthermore,the number of channels of the recently developed tomographic apparatuses are increased and since all the channel data must be subjected to the convolution operation,the number of data to be processed is increased. When the number of channel data used in one convolution processing is increased so that the number of data to be processed is increased, the load on the computer for carrying out the convolution becomes heavy,thereby hindering an image reconstruction at a high speed.

Prior art document US-A-4 250 387 discloses a computerized tomographic X-ray apparatus which directs X-rays, usually in a fan-shaped distribution, through the body of a patient. In some examples the fan distribution may subtend angles of 50° or more at the source. It has been found that such tubes, particularly of the rotating anode type, tend to have X-ray emission from regions surrounding the focal spot and it is not convenient to use anode shields to eliminate it. This off-focus radiation can present problems, especially when attenuators are used to equalize absorbing paths through the patient, since the off-focus radiation can sometimes be less attenuated than the main beam. It is proposed to correct the signals produced by the X-ray detectors for off-focus radiation. A profile of off-focus or halo radition is produced and the attenuation imposed on it is estimated. The estimates are used to suitably modify the signals produced by the X-ray detectors so as to correct for the presence of off-focus radiation.

It is an object of the present invention to realize a deconvolution processing method which can decrease the load on a computer even when the range of a blur due to the radiation of X-rays from afocal points is large.

To solve this object the present invention provides a method as specified in claim 1.

The data of each channel of an X-ray detector are produced by the weighted addition of the data by measuring from alternating channels of the preceeding channels including a plurality of channels of said each channel and also the data obtained by measuring the succeeding channels consisting of a plurality of channels of said each channel.

Brief Description of The Drawings

Fig.1 is a view schematically illustrating the construction of an X-ray tomographic apparatus used to carry out the method in accordance with the present invention;
Fig.3 is a view illustrating the mechanism for radiating and detecting the X-rays thereof;
Fig.4 is a schematic view illustrating an X-ray radiation unit in an X-ray tube;
Fig.5 is a view illustrating the projection data of a pin target; and
Figs.6A,6B and 6C are views used to explain the convolution processing method.

Best Mode For Carrying Out The Invention

Now an embodiment of the present invention will be described in detail with reference to the accompanying drawings. In Fig.1, the X-rays which are radiated from the X-ray tube 1,transmitted through the reconstruction region 3 and impinge on the multi-channel X-ray detector 4 are converted into multi-channel electrical signals by the detector which in turn are acquired by a data acquisition device 12. The acquired data are delivered to a data correction device 13 so that a predetermined correction such as the X-ray strength corretion is carried out. The corrected data is subjected to the deconvolution processing in a deconvolution device 14 in order to eliminate a blur. Next the -log operation is carried out by a -log operation device and the output therefrom is subjected to the image reconstruction process by a reconstruction device. The reconstructed image is displayed by a display device.

The data processing by the appparatus with the above-described construction will be described in detail with reference to a flowchart shown in Fig.2. The data obtained by the data acqusion device 12 is subjected to the X-ray strength correction in the step I so that variations in data due to variations in X-ray strength are corrected and in the step II variations in data due to the differences in sensitivity among the channels of the X-ray detector 4 are corrected. These corrections are the general correcions carried out by the tomographic apparatus and are carried out by a data correction device 13. In a convlution device 14 the data corrected in the manner described above is subjected to a first convolution processing in the step III and then a second convolution processing in the step IV by a deconvolution device 14. The first stage deconvolution processing is carried out to eliminate a blur which has a great width due to the radiation of the X-ray radiation from the afocal points and the second stage deconvlution processing is carried out to eliminate a blur which is caused by the radiation of the X-rays from the plane focal point and which has a width smaller than that of the blur due to the radiation of the X-rays from the afocal points. These deconvlution processings are carried out as follows.

The first stage deconvolution is carried out based on the following equation:

$$D_i = \sum_{j=-M}^{M} L_{ij} \cdot U_{i-2j} \qquad (1)$$

where

L_{ij} : a weight factor used in the first stage convolution processing;
U_i: data of a channel i prior to the deconvolution processing;
D_i: data of a channel i after the first stage deconvolution processing;and
i: a channel number.

The above-mentioned equation (1) means that the deconvolution processing is carried out by using the data obtained from alternating channels from 2M channels preceeding a channel i and from 2M channels succeeding the channel i. The value of 2M is selected as a large number in correspondence with the large width range of a blur due the radiation of the X-rays from the afocal points,but the data used in convolution

are alternately selected, the convolution processing can be carried out by using the data which is only one half of the data corresponding to the range of blur. As a result, the load on the computer can be decreased. The convolution processing described above is repeated for the data of all the channels.

The second stage deconvolution is carried out based on the following equation:

$$E_1 = \sum_{i=-N}^{N} K_{ij} \cdot D_{i-j} \qquad (2)$$

where

K_{ij}: a weight factor used in the second state deconvolution;
Di : data of a channel i after the first stage deconvolution;and
E_i : data of the channel i after the second stage deconvolution

The above-mentioned equation (2) means that the deconvlution is carried out by using the data of all of a number of N channels preceeding said each channel i as well as the data of all of a number of N channels succeeding said each channel i. The second stage deconvolutuon processing is similar to the convnetional deconvolution processing,but since it is carried out after the first stage deconvolution processing has been carried out, the range N of the channels may be narrower than that of the conventional deconvolution processing.It follows therefore that the number or data used in the second stage deconvolution are less in number and consequently the load imposed on the computer becomes light.

It must be pointed out there that it is not aways necessary to carry out the second stage and that it may be eliminated when a blur has been satisfactorily eliminated only by the first stage deconvolution processing. The first and second deconvlution processings are carried out in two stages,but they can be carried out in one stage as will be described below. That is, of all the channels proceeding to and suceeding from a predetermined channel, all the channels in the vicinity of said predetermined channel are used and of the channels except those in the vicinity of said predetermined channel,alternately selected channels are used in the deconvolution processing. Then the same result as that attained by the first and second stage processings are carried out in two stages.

The data which has undergone such deconvolution processings is converted to the data representative of the X-ray absrobed dose by the -log operation in the step V and after filtering in the the step VI,the converted data is subjected to the back projection processing in the step VII so that an image is reconstructed. The reconstructed image is converted into a CT value in the step VIII. The processing of the data after the step V is the general data processing carried out in the conventional tomographic apparatus by the -log operation device 15 and the reconstruction device 16.

Claims

1. A method of operating an X-ray tomographic apparatus for eliminating a blur in an image resulting from the image reconstruction by utilising data obtained from a multi-channel X-ray detector which detects the X-ray transmitted through an image reconstruction region to which are radiated the X-rays, which comprises the step of producing data for each channel i by the weighted addition of the measured data of a plurality of channels preceding and succeeding each channel, wherein said weighted addition is of the form

$$D_i = \sum_{j=0}^{M} P_{ij} \cdot U_{i-N-2j} + \sum_{j=-N}^{N} L_{ij} \cdot U_{i+j} + \sum_{j=0}^{M} P_{ij} \cdot U_{i+N+2j}$$

where
U_i is the measured data for channel i
D_i is the produced data for channel i
L_{ij} and P_{ij} are non-zero weights
N is a non-negative integer
and characterised in that M is a positive integer.

2. The method of claim 1 with N = 0.

3. The method of claim 2 wherein said method further comprises a second step of producing second data E_i for each channel i by a weighted addition of the form

$$E_i = \sum_{j=-Q}^{Q} K_{ij} \cdot D_{i+j}$$

where
K_{ij} are non-zero weights and
Q is a positive integer smaller than M.

Patentansprüche

1. Konvolutionsrechenverfahren zum Betrieb einer Röntgen-Tomographie-Anlage zum Eliminieren eines Makels oder Schattens, der aus der Bildrekonstruktion bei Verwendung von Werten resultiert, die von einem Vielkanal-Röntgendetektor erhalten wurden, der die Röntgenstrahlen detektiert, die durch einen Bildrekonstruktionsbereich übertragen wurden, auf den die Röntgenstrahlen gestrahlt wurden, wobei das Verfahren den Schritt umfaßt, Werte für jeden Kanal i durch die gewichtete Addition der gemessenen Werte einer Vielzahl von Kanälen zu erzeugen, die jedem Kanal vorangehen und nachfolgen, wobei die gewichtete Addition in der Form ist

$$D_i = \sum_{j=0}^{M} P_{ij} \cdot U_{i-N-2j} + \sum_{j=-N}^{N} L_{ij} \cdot U_{i+j} + \sum_{j=0}^{M} P_{ij} \cdot U_{i+N+2j}$$

worin
U_i der gemessene Wert für Kanal i ist
D_i der erzeugte Wert für Kanal i ist
L_{ij} und P_{ij} nicht-nullwertige Gewichtungen sind
N eine nicht negative ganze Zahl ist,
und dadurch charakterisiert ist,
daß M eine positive ganze Zahl ist.

2. Verfahren nach Anspruch 1 mit N = 0.

3. Verfahren nach Anspruch 2, wobei das Verfahren ferner einen zweiten Schritt umfaßt, einen zweiten Wert E_i für jeden Kanal i durch eine gewichtete Addition zu erzeugen, die die Form hat

$$E_i = \sum_{j=-Q}^{Q} K_{ij} \cdot D_{i+j}$$

worin
K_{ij} nicht-nullwertige Gewichtungen sind und
Q eine positive ganze Zahl kleiner als M ist.

Revendications

1. Un procédé de fonctionnement d'un appareil tomographique aux rayons X pour éliminer une tâche d'une image résultant de la reconstruction d'image en utilisant des données obtenues à partir d'un détecteur de rayons X à canaux multiples qui détecte les rayons X transmis à travers la région de reconstruction d'image sur laquelle sont envoyés les rayons X, qui comporte la phase consistant à produire des données pour chaque canal i par l'addition pondérée des données mesurées d'une

pluralité de canaux précédant et suivant chaque canal, dans lequel ladite addition pondérée est sous la forme

$$D_i = \sum_{j=o}^{M} P_{ij} \cdot U_{i-N-2j} + \sum_{j=-N}^{N} L_{ij} \cdot U_{i+j} + \sum_{j=o}^{M} P_{ij} \cdot U_{i+N+2j}$$

dans laquelle
U_i est la donnée mesurée pour le canal i
D_i est la donnée produite pour le canal i
L_{ij} et P_{ij} sont des poids non nuls
N est un nombre entier non-négatif
et caractérisé en ce que M est un nombre entier positif.

2. Le procédé de la revendication 1, dans lequel N = 0.

3. Le procédé de la revendication 2, dans lequel ledit procédé comporte au surplus une seconde phase consistant à produire des secondes données E_i pour chaque canal i par une addition pondérée de la forme

$$E_i = \sum_{j=-Q}^{Q} K_{ij} \cdot D_{i+j}$$

dans laquelle
K_{ij} sont des poids non nuls et
Q est un nombre entier positif inférieur à M.

Fig. 1

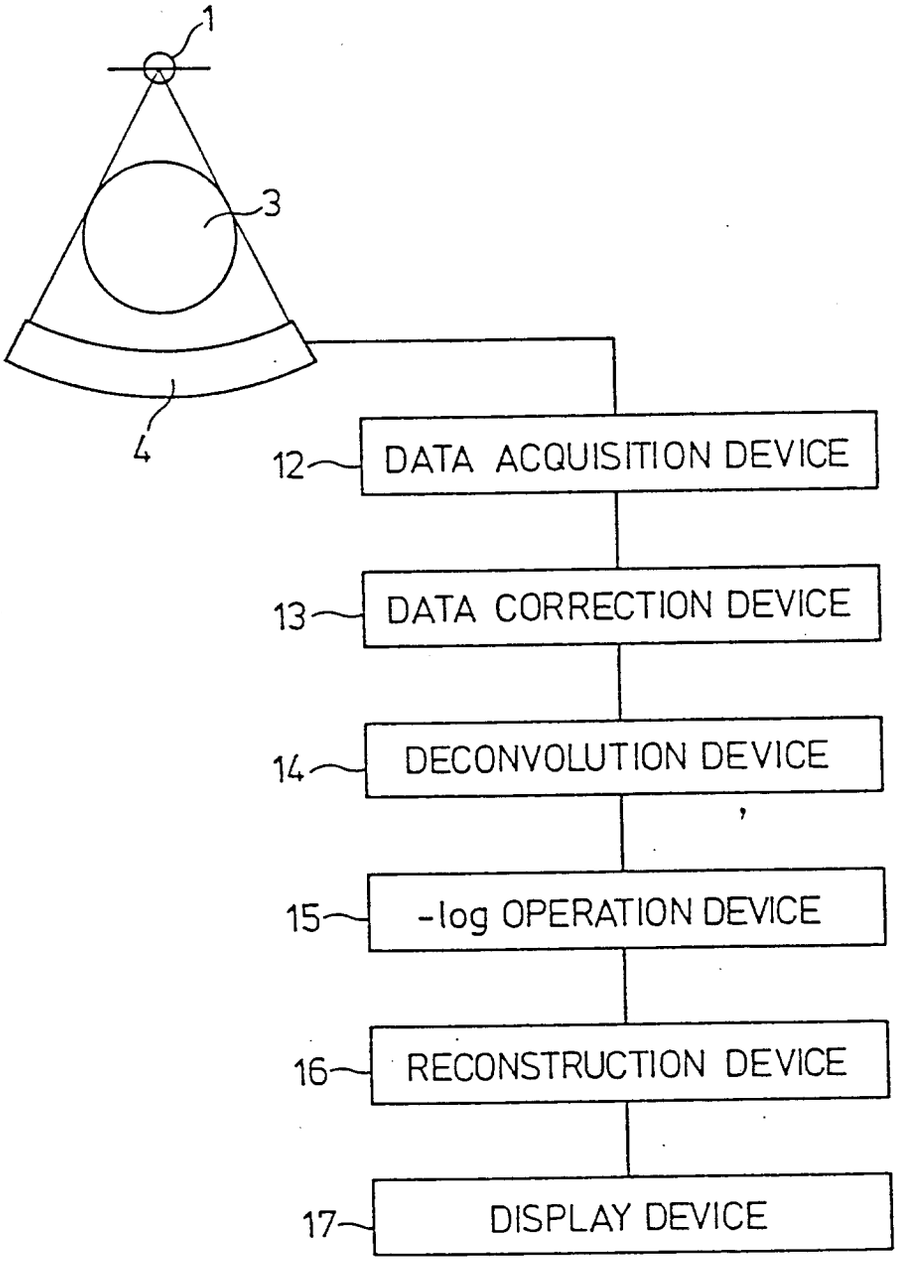

1
3
4
12
DATA ACQUISITION DEVICE
13
DATA CORRECTION DEVICE
14
DECONVOLUTION DEVICE
15
-log OPERATION DEVICE
16
RECONSTRUCTION DEVICE
17
DISPLAY DEVICE

Fig.2

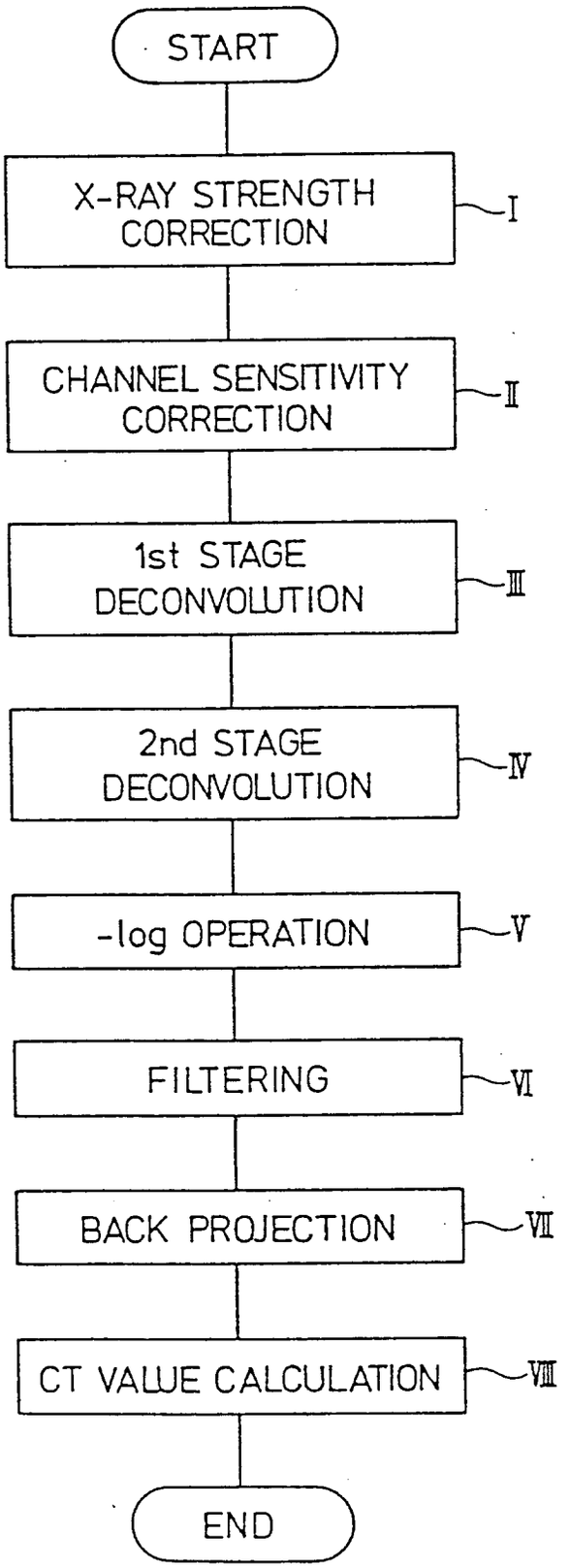

START
X-RAY STRENGTH CORRECTION
I
CHANNEL SENSITIVITY CORRECTION
II
1st STAGE DECONVOLUTION
III
2nd STAGE DECONVOLUTION
IV
-log OPERATION
V
FILTERING
VI
BACK PROJECTION
VII
CT VALUE CALCULATION
VIII
END

Fig. 3

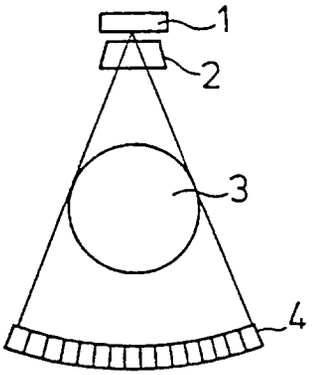


Fig. 4

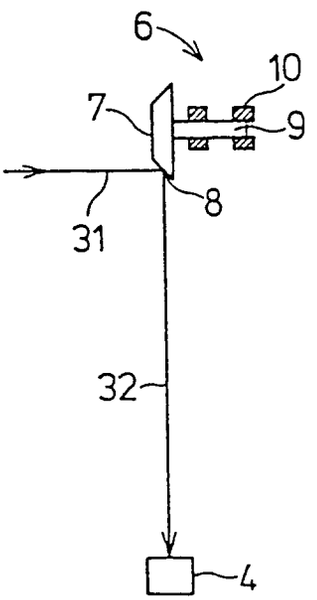


Fig.5

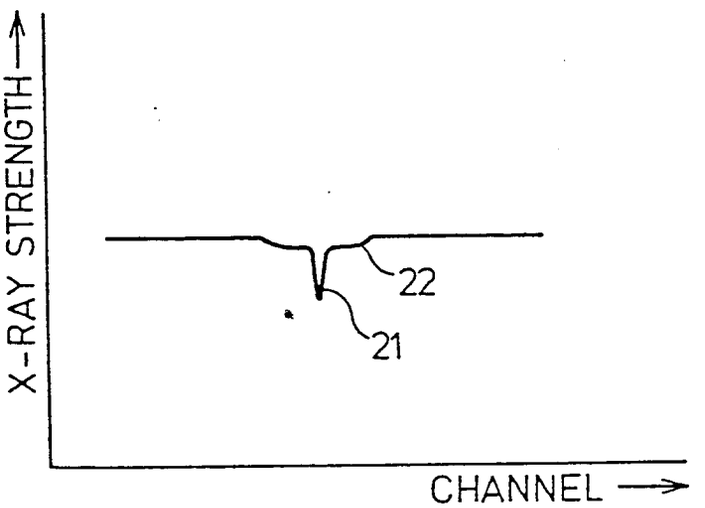


Fig. 6A

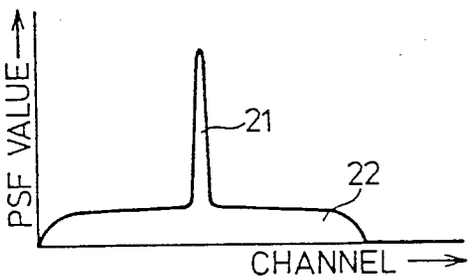


Fig. 6B

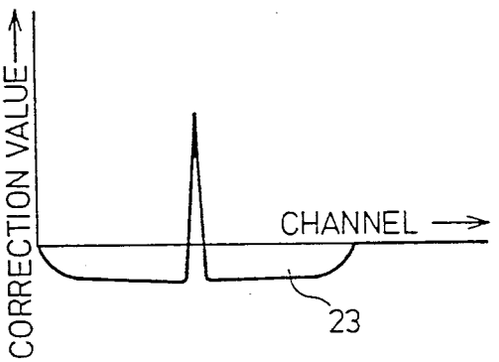


Fig. 6C

